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ENGINEERING AND DEVELOPMENT PROGRAM PLAN, ANTIMISTING FUEL.(U)
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(6) # ENGINEERING AND DEVELOPMENT PROGRAM PLAN ANTIMISTING FUEL,

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U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
TECHNICAL CENTER
Atlantic City Airport, New Jersey 08405

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16. Abstract

A phased program is identified to direct research and development efforts to: (a) determine if the use of antimisting fuel is feasible; (b) develop recommendations as to its introduction and use in civil aviation operations; and (c) demonstrate its effectiveness in a crash instance, and (d) assess the economic reasonableness in support of regulatory actions. The basic program utilizes an existing high molecular weight polymer additive dissolved in kerosene using a carrier fluid as a representative agent to prove the concept of uses of such fuels. Parallel to this main effort are investigations to identify other potentially acceptable fuels. Estimated funding and proposed scheduling are included.

17. Key Words
Crash fire safety, antimisting fuels, fuel specifications, flammability, kerosene, fuel additives, crash tests

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METRIC CONVERSION FACTORS

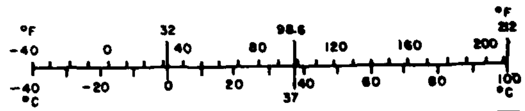
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10 286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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EXECUTIVE SUMMARY

PROBLEM STATEMENT.

Impact-survivable commercial, turbine-powered aircraft crashes have occurred where fuel is released from ruptured wing and fuselage tanks in a manner that often results in the fuel being in the form of a fine mist. Ever present, random ignition sources are also present in such cases with the end result being a "fireball" that can envelope the aircraft as it comes to a rest. In such crashes, approximately 30 percent of the fatalities are related to the presence of fire and/or its related heat, smoke, and toxic fumes.

BACKGROUND.

Suppression of the tendency of the turbine fuel to form the fine mist responsible for the fireball leads to the speculation that up to 30 percent of the fatalities can be reduced. Such fuel modifying additives for use in civil aviation turbine aircraft have been and continued to be identified. They have the potential to achieve the goal of suppression of the misting characteristic under stress application, while still being usable in the engine and aircraft fuel system. The feasibility of using such antimisting fuels in commercial aircraft, the techniques and procedures to evaluate the effectivity of such fuels, the logistics and feasibility of production of such fuel in sufficient quantity to meet worldwide demands, and the economic viability associated with its use are the subjects of this Engineering and Development Program Plan.

Recent work has identified fuels in which the change of fuel misting properties is by addition of a relatively low concentration of very high molecular weight polymers. These type fuels are most promising in that the weight penalty factor is low and fuel stability appears to be capable of development to an acceptable level.

CRITICAL ISSUES.

The issues raised above can be more clearly stated by addressing them in the form of specific questions. Solutions to these questions would resolve the issues raised. The specific questions in evaluating the future potential of antimisting fuel for worldwide commercial service have been identified as:

1. Can the modified fuel be made available in adequate quantities and at an acceptable cost with adequate control of quality for worldwide deployment?

2. What degree of protection would the antimisting fuel provide in post-crash fuel fires?

   a. A few minutes after refueling; i.e., typically in the takeoff case.

   b. At the end of a flight cycle; i.e., typically in the approach/landing case.

3. What changes, if any, are necessary to enable a civil aircraft to use the antimisting fuel? For example, are changes necessary to fuel system tanks, pumps, filters, etc., and/or to the engine fuel management system?

4. Is it feasible in day-to-day commercial operation to blend the fuel at the fueling point?

5. Must the antimisting fuel be degraded (subjected to some mechanical shearing or other process) before it is suitable for operation in an engine system, and if so, how can this controlled degradation be achieved?

ALTERNATIVE TECHNICAL APPROACHES.

Alternative approaches to the misting problem of fuel upon ejection from a ruptured fuel tank do not exist. The only relief seen is to contain the fuel.

TECHNICAL APPROACH.

A multiphased effort defines the full scope of the program plan for the development of antimisting fuel, utilizing the most promising of the antimisting fuels presently known. Overall schedules and costs are shown on pages vii and viii. Outlined below are summaries of content for each phase.

FEASIBILITY/FM-9 DEVELOPMENT. Presently, the most promising fuel is the Imperial Chemical Industries of America (ICI Americas) FM-9 additive. This additive, a high molecular weight polymer, is dissolved in kerosene using a carrier fluid. This additive, having been under investigation since the early 1970's, presents a very large data base to draw upon in proving the overall concept. The acceptability of use of this fuel will be examined through the establishment of its basic characteristics, by analysis, by devising laboratory scale tests, by subjection to large-scale tests, and by identification of major problem areas associated with the use in airport, aircraft, and engine systems. Production, quality control, and cost will also be examined. Combination of all of these factors will provide an answer as to the feasibility of the use of such fuel and the scope of effort required to produce a successful fuel, should the feasibility be established.

FULL-SCALE VALIDATION. The FAA will concentrate feasibility efforts on FM-9, in order that a demonstration flight and crash test can be completed by the end of FY 1984. The successful consummation of these tests will provide the Associate Administrator for Aviation Standards ample evidence to consider rulemaking action. The full-scale crash demonstration test is intended to provide proof of concept for proposed rulemaking and in no way is intended to serve as a precedence or prerequisite for future fuel acceptance. Acceptance of other potential antimisting fuel will be predicated upon other criteria and tests developed during the evolution of this program.

CANDIDATE FUELS EVALUATION. The development program plan for FM-9 is based on the integration of numerous complex elements into a total system demonstration. During the continuing system compatibility testing, certain characteristics may arise that are clearly not technically solvable within the time phase of this program. In addition, preliminary cost estimates show that the economics of this additive to be substantially high. The FAA intends to encourage the development of other additives or approaches because of these potential problems and the added potential of effective cost avoidance. The criteria that emerges from FM-9 development will serve as evaluation tools to establish the merits of other additives or approaches.

The desire for being able to go to a proposed rulemaking posture in FY 1984 serves as a driving force to initiate such ancilliary evaluations as early as

possible. The FAA will accept information concerning alternate fuels and analyze their potential to perform in an equal or better fashion than FM-9.

The FAA will encourage an immediate alternate fuel development to insure that the most effective results are obtained prior to proposed rulemaking. To this end, funding will be provided to manufacturers to present evidence of a promising alternate fuel. Those alternate fuels presented to FAA will be assessed relative to their merit by FY 1983. At this time, a decision concerning which fuel is carried to final demonstration will be made.

PROGRAM INTERFACES/ORGANIZATION.

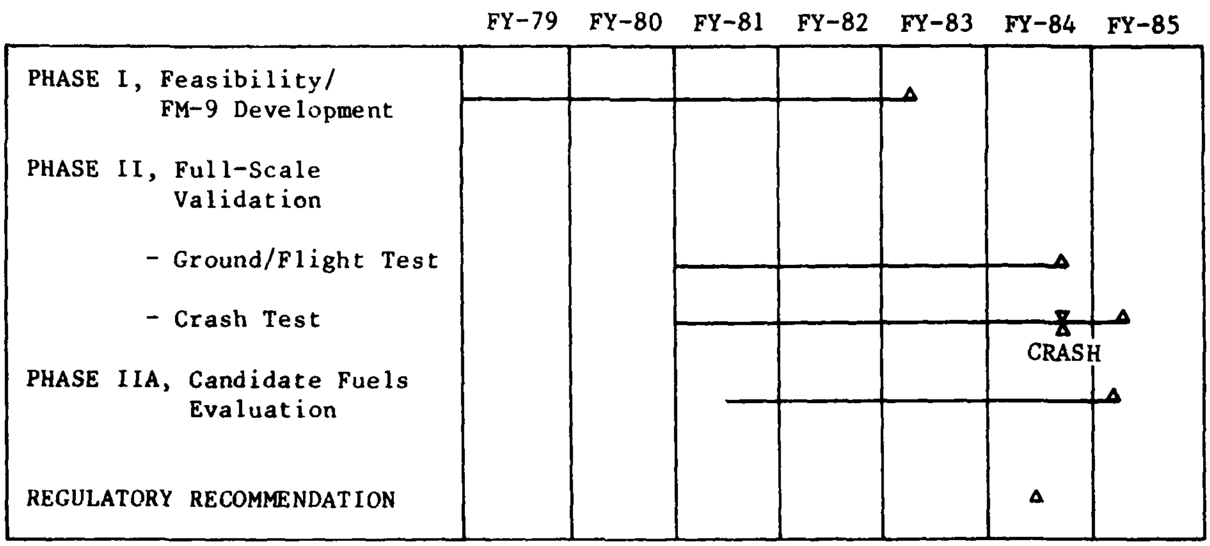
Department of Transportation (DOT)/FAA interest in the concept of use of antimisting fuels to control or reduce post-crash fire fatalities has been active since early in the 1960-1970 decade. Various techniques such as the use of gelled fuels, emulsified fuels, and systems incorporating such features as instant solidification of fuel upon impact or demand have been investigated to varying degrees. The trend has steadily developed in the direction of the use of a fuel, modified to its antimisting state, carried onboard as would normal fuel without provision or requirement for necessary action upon the fuel to give its flammability protection.

The most promising of the antimisting fuels at present is manufactured by Imperial Chemical Industries, (ICI) Americas and ICI Ltd. of Great Britain (ICI Ltd.). The fuel is basically ASTM D1655 specification kerosene which contains an additive and additive carrier fluid, both of which are proprietary to ICI Americas. The additive and carrier fluid result in the kerosene being altered to contain uniform, long chain polymer substances which resist the tendency to mist, especially when subjected to moderate external stress.

Because of the promise shown by this fuel, referred to as FM-9, in preliminary laboratory testing and because of the proprietary nature of the fuel, the United States (U.S.) and the United Kingdom (U.K.) entered into a Memorandum of Understanding (MOU) in June 1978, appendix A, to "cooperate in the examination, development, and testing of antimisting kerosene fuels and of equipment related to the use of such fuels." The ICI Americas FM-9 antimisting fuel would be used as the vehicle to develop the procedures, techniques, and evaluation equipment for future examination of antimisting fuel candidates.

The main participants in the MOU are the DOT/FAA, the Royal Aircraft Establishment (RAE) of the U.K., with the National Aeronautics and Space Administration (NASA) as a third party to undertake any basic research aspects of the work as may be required of the U.S. participants, in line with the NASA mission.

OVERALL ANTIMISTING FUEL PROGRAM PROPOSED SCHEDULING



OVERALL ANTIMISTING FUEL PROGRAM FUNDING AND MANPOWER SUMMARY

	FY-79	FY-80	FY-81	FY-82	FY-83	FY-84	FY-85
PHASE I, Feasibility/ FM-9 Development	1075	1912	1195	605			
PHASE II, Full-Scale Validation							
- Ground/Flight Test			250	570	675	725	
- Crash Test				625	1700	535	410
PHASE IIA, Candidate Fuels Evaluation			550	1490	1100	100	
Subtotal $	1075K	1912K	1995K	3290K	3475K	1360K	410K
Subtotal MY	9	12	14	15	15	9	2

Note: Funding estimates for FY-1981 through FY-1985 are based on FY-80 dollars.
K = $1,000
MY = Man Year

1. INTRODUCTION/BACKGROUND.

Fire fatalities associated with impact survivable aircraft crashes are a major concern in aviation operations. Typically in a survivable aircraft crash, large quantities of fuel are ejected into the airstream from ruptured tanks and fuel lines. Under these conditions, fuel sheared by the high-velocity airstream results in a highly flammable mist, easily ignited, and, at times explosive, igniting pools of fuel in and around the damaged aircraft.

Previous research efforts to preclude fuel fires under survivable crash conditions had produced fuel in the form of gels and emulsions which proved to be incompatible with aircraft systems and operations.

Recent experiments have produced an antimisting kerosene additive that indicates a potential for precluding the fine mist and associated "fireball" and exhibits potential for allowing restoration of the filtration and atomizing characteristics—a major requirement for aircraft engine and fuel systems operation.

1.1 OBJECTIVE.

This plan defines the efforts required to test the most promising antimisting fuel currently available and to develop procedures, techniques, and equipment for use in defining an antimisting fuel specification that will form the basis for rulemaking. To realize the potential offered by such fuels, the logical sequence of tasks outlined herein will provide the FAA with a technical data base to determine whether rulemaking on antimisting fuels for commercial aircraft operations is feasible. The proposed scheduling and recommended funding to achieve this overall objective are shown in appendix B. The major phases and decision points are:

1.1.1 Feasibility/FM-9 Development.

Making use of the most promising of the antimisting fuel candidates presently known, (ICI Americas, FM-9) the feasibility of the use of this type fuel will be examined by establishment of the basic characteristics of the fuel and their relationship to the desired goal of reduction of fuel misting under crash conditions.

In the process of such examinations, procedures, techniques, and necessary equipment will be developed to allow other potentially effective antimisting fuels to be systematically evaluated. These will cover such areas as the flammability characteristics, the rheology of the fuel and associated quality control requirements, the fuel's compatibility with engine, aircraft, and airport handling systems, the development of an outline for a revised fuel specification and definition of problems associated with the blending, degrading (if necessary), and storage of the fuel.

This process will carry through to large-scale crash evaluations and the cost/benefit aspects of the use of antimisting fuels.

A goal of this first phase is an early decision as to whether feasibility exists toward introduction of antimisting fuel into civil aviation, as delineated in the Memorandum of Understanding (MOU).

1.1.2 FM-9 Development.

Pending a positive decision at the end of the feasibility portion of Phase I to use antimisting fuels in civil aviation, solution of the problem areas identified in the use of FM-9 will be undertaken. Solutions will be directed toward the use of breadboard or prototype equipment. Such systems will be developed only to the degree necessary to support the final ground, flight, and full-scale crash demonstrations.

1.1.3 Candidate Fuels Development.

To assure that a maximum effort is made to develop an antimisting fuel, the FAA intends to establish and carry the work of the alternate fuels development phase in parallel as a stop gap against failure of FM-9. Introduction of any alternate fuel candidates beyond FY-82 cannot be accepted without a slippage of the desired regulatory date.

This parallel fuels development phase relies upon submission of data by manufacturers of such alternate fuels that can be evaluated or verified by the FAA. These evaluations or verifications will utilize the procedures, equipments, and tests which emerge from the FM-9 development work.

FAA will solicit such fuels from suppliers with "seed" funding. Such information and data which industry provides for these candidate fuels will be rated by FAA and the best will be funded with additional development money. A decision must be made by FY-1983 whether FM-9 or the alternate fuel will be further developed. The degree of advantage between the alternate and the FM-9 will be the criterion.

The economics and logistics of fuel supply, the regulations governing the production and usage, and the schedule of implementation will be a main thrust of both the FM-9 and alternate fuel phases effort. These items will be examined and recommendations concerning them will be made to the regulatory side of the FAA.

1.1.4 Ground, Flight, Test And Full-Scale Crash Demonstration.

Regardless of whether FM-9 or an alternate fuel is chosen, the conduct of ground test in a full-scale aircraft, the flight test in a full-scale aircraft, and the full-scale crash demonstration are intended to be done only once to prove the concept of use.

Upon successful completion of these major tests, the FAA will identify a fuel specification, appropriate test methods or procedures, and make available to industry the technology arrived at during these efforts to support further and future development of fuels by industry.

1.2 CRITICAL ISSUES.

The antimisting fuel program plan is designed, through the logical progression of tasks listed, to resolve what are considered to be the major critical issues. These issues are:

a. Can the fuel be made available in adequate quantities and at an acceptable cost with adequate control of quality for worldwide deployment?

b. What degree of protection would antimisting fuel provide in post-crash fuel fires?

1. A few minutes after refueling; i.e., typically in the takeoff case.

2. At the end of a flight cycle; i.e., typically in the approach/landing case.

c. What changes, if any, are necessary to enable a civil aircraft to use antimisting fuel? For example, are changes necessary to the fuel system tanks, pumps, filters, etc., and/or to the engine fuel management system?

d. Is it feasible in day-to-day commercial operation to blend the additive with the fuel at the fueling point?

e. Must antimisting fuel be degraded before it is suitable for operation in an engine system, and how can this controlled degradation be achieved?

1.3 PROGRAM MANAGEMENT.

The antimisting fuel program is structured to utilize the MOU between the United States (U.S.) and the United Kingdom (U.K.) during the conduct of the first phase. This MOU defines the cooperative efforts to be undertaken in the determination of the feasibility of introducing antimisting fuel into civil aviation, using the most promising of these fuels, FM-9.

A decision resulting from the first phase work that feasibility does indeed exist for such introduction of these fuels would open the way for solicitation of input and additional antimisting fuel candidates from industry.

1.3.1 Initial Phase Management Functions/Responsibilities.

The principal participants under the Phase I, Feasibility/FM-9 Development, are the DOT/FAA and the RAE with NASA as a major supporter of the DOT/FAA (appendix C).

Specific breakdown of responsibilities pertinent to the various tasks as outlined in the MOU.

a. DOT/FAA

Aircraft, engine, and airport fuel system compatibility
Large-scale crash flammability resistance
Flammability characteristics determination
Rheological properties

b. U.K./RAE

Production
Blending
Flammability characteristics
Rheology
Fuel system compatibilities

c. U.S./NASA

Engine fuel system components
Basic rheology

Duplication of some tasks is intentional within this management scheme for those tasks where technology differences between the industries of the two countries (U.S. and U.K.) could affect the results, and in those areas where the potential impact on the decision process are significant.

The DOT/FAA functions to be carried out in this management scheme are as follows:

a. Directs all engineering and development activities as outlined in this Program Plan.

b. Develops budgetary and fiscal programs required to implement the anti-misting fuels program. Coordinates and/or submits for approval all procurement requests for contractual and interagency agreements in accordance with established procedures.

c. Defines projects, tasks, and priorities required for implementation.

d. Assures that tasks and projects are effectively directed toward the critical issues as defined in this plan.

e. Maintains cognizance over development technology status and progress achieved in executing this plan.

f. Provides for technical consultation and assistance from other offices and services within the FAA or DOT and with other government agencies and aviation organizations.

1.4 PROGRAM COORDINATION.

The responsibility for coordination of the antimisting fuels technical program through the initial phase rests with the joint chairmen of the antimisting fuels technical committee as defined in the MOU. Beyond the first phase, the program responsibility rests entirely with the DOT/FAA.

2. TECHNICAL APPROACH.

The technical details, proposed schedules, and recommended funding levels for the individual tasks to achieve answers to the questions and problems posed in the above phases are described in this section.

2.1 PHASE I—FEASIBILITY/FM-9 DEVELOPMENT.

The most promising antimisting fuel presently known is a combination of kerosene, a proprietary polymeric additive manufactured by Imperial Chemical Industries, Americas, (ICI). This fuel additive, known as FM-9, will be utilized in this first phase to define the feasibility of the use of antimisting fuels in civil aviation

and to outline the scope of effort needed to carry through to a recommendation for introduction of the fuel into civil aviation use. The overall phase is divided into four subparts:

a. Basic test/characteristics
b. Large-scale evaluations
c. Cost/benefit considerations
d. Decision of feasibility

2.1.1 Basic Tests/Characteristics.

The intent of this work is to establish a series of procedures, techniques, equipments, etc., to investigate the properties of the FM-9 fuel. Additionally, the necessary screening tools and technology to assess the acceptability of other candidate antimisting fuels are expected to emerge from the work. Within this framework, the following are to be examined:

2.1.1.1 Establishment of Flammability Limits.

The individual projects to be investigated in the establishment of antimisting fuels flammability characteristics are briefly discussed below:

Laboratory-scale flammability test will be established using documented techniques, procedures, and equipment that will allow reliable examination of antimisting fuels with a minimal amount of test fluid being required.

The possibility that small quantities of degraded antimisting fuel may be present in a crash instance must be investigated. Such degraded fuel could be released from components of the engine; the presence of fuel in this form could have an impact upon the antimist flammability of the fuel.

Likewise, the presence of other flammables, such as engine lubricating oil, hydraulic fluids, etc., may impact upon the antimisting quality of the fuel. Investigations to examine whether ignition of such fluids could alter the antimisting characteristics are necessary.

In crash instances, the types of ignition sources are expected to be varied. Whether the ignition intensity associated with hot engine parts, electrical sparking due to broken cables, or the sparking produced by metal scraping, can impact the ignition and flame propagation character of the fuel must be identified.

Definition of the droplet size and distribution of fuel particles will be examined to determine if a critical configuration can exist.

A similar concern exists regarding whether the flame propagation rate in an antimisting fuel has a critical value that would impact the protection offered by the fuel.

Throughout most of the investigations to identify the quality of antimisting fuel candidates, the assessment of a "pass" or "fail" test must be made. In all likelihood, this definition will undergo considerable modification. The importance of this definition is reflected most in the evaluation of flammability data from various sources and tests.

In this subphase of work, there will be continual concern about whether the antimisting fuel demonstrates a tendency to ignite pools of fuel that are likely to collect in a crash instance. While antimisting refers mostly to the droplet formation character, the post-crash fuel pool must not tend to ignite more readily or propagate flame more rapidly if they are directly exposed to ignition sources. The mechanisms of this occurrence will be examined and identified.

2.1.1.2 Evaluation of Rheology Relative to Quality Control.

Examination of the basic rheology of the fuel will occur through a series of efforts to establish what problems may exist in setting quality control for a uniform product. The individual efforts are briefly described as follows:

One of the rheological properties of antimisting fuels that is felt to be significant in establishing the relative quality of the fuels flammability characteristics is the viscosity. Since this fuel follows non-Newtonian Laws, the normal measurement techniques do not produce repeatable, reliable results. Therefore, evaluation and development of a system is necessary.

Parallel with the viscosity measurement technique development, the relationship to the flammability characteristics must be determined. This information will be derived from laboratory, small-scale, and large-scale flammability tests that are conducted.

The previous two efforts dealt with modified fuel in a virgin state (prior to shear degradation). Various pumps, filters, fittings, etc., may introduce a level of shear that destroys the antimisting flammability of the fuel. The relating of the level of shear, or the rate of shear, to the viscosity may give indication of the continuance of protective flame characteristics.

With the antimisting fuel exhibiting non-Newtonian characteristics, there is concern that the heat transfer characteristics may not be sufficient to perform one of the other major functions of the fuel; that is, the extraction of heat from the bearing lubricating oil. These transfer coefficients will be established and related to engine flow and temperature limits.

Moving through an engine fuel system, the last operation is the spray and vaporization to produce the proper heat release in the combustor. Paradoxically, the antimisting quality is detrimental to this operation. Investigations must be conducted to establish if the present systems can produce an acceptable pattern within the combustor and if not, what limitations must be placed upon the fuel or what modifcations to the engine system are required.

To achieve the results described in all of the previous work of this subphase, techniques and procedures that are alien to present practices will most likely evolve. To assure that the basis for quality control is maintained, the normal American Society for Testing Materials (ASTM) test methods must be assessed and, if necessary, revised to give uniformity of result regardless of where in the fuel history or production system the conversion to an antimisting grade of fuel is accomplished. These revised test methods, if deemed necessary, must be fully coordinated, acceptable, and understood by all segments of the fuel and aircraft industries.

In the event the spray and/or vaporization required by the engine combustion system cannot be achieved by working on the normal components, such as filters, pumps, nozzles, etc., a new function must be introduced into the engine/aircraft fuel system, that of intentional degradation. Such techniques and/or equipment must be power efficient and lightweight. Efforts to examine methods of intentional shearing or degrading of the fuel to produce acceptable engine cycle operation will be conducted.

The blending of the fuel can, theoretically, be done at the refinery, at the airport, or at the delivery point to the aircraft. The antimisting fuel normally requires a period of stabilization for the full benefit in antimisting flammability control to develop. Obviously, if bulk blending techniques are applied to the blending of the fuel at the delivery point to the aircraft, this time requirment might not be met. Examination of the techniques will be made to assure that the desired characteristics are achieved, considering time factors and possible blending location.

An important rheological property that must be established for the antimisting fuel is its affinity for water. Suspension of large quantities of water destroy the antiflammability characteristics by causing a precipitation of the substances that provide the desired qualities. Additionally, if the propensity for water is great, fuel icing may occur and heat transfer characteristics may be adversely affected.

Within this subphase, the final area of consideration is assurance that the aircraft and engine systems will be able to function properly. Flow rates in various pipeline and transfer systems cannot be restricted if normal operations are expected. The pipe, fittings, adapters, etc., that are common to aircraft and engine systems will be examined to assure proper coefficients and delivery rates.

2.1.1.3 Compatibility.

The problems associated with the compatibility of the antimisting fuel and aircraft, engine, and airport systems will be examined through the following efforts:

In order to establish the applicability of the use of the antimisting fuel to the civil aviation fleet, surveys of engine, aircraft, and airport fuel handling systems will be conducted. These surveys will encompass both existing and anticipated systems.

Use of aircraft fuel system simulators and engine bench testing of components will be employed to identify critical operational problem areas associated with the use of the antimisting fuel. Attention will be paid to these operations at temperature extremes.

Combustor rig test techniques will be employed to evaluate the problems that may be associated with engine starting. These startng tests will cover hot and cold ambient ground tests, as well as altitude relight capabilities using the antimisting fuel.

Because of the expected difficulties in achieving both goals of antimisting fuel—that of not causing a fine mist in a crash impact instance but, at the same time, burning properly in the engine to meet the mission requirement, the

resulting environmental emission of pollutants is suspect. This will be documented and analyses will be conducted to determine if advanced low emission combustor techniques are appropriate for use with the antimisting fuel.

Advanced technology engines operate at very elevated turbine inlet temperatures, and because of the detrimental impact of these high temperatures on the turbine blade and stator life, complex systems are utilized to control the temperatures of the parts. There is concern that because of the enhanced gum content of the antimisting fuel, and because of the usual practice of adding substances to achieve the antimisting property, the turbine film cooling passages, which are very small, may be clogged, or other types of turbine cooling control system, such as ceramics, may be adversely affected. Evaluations and analyses of these areas will be conducted.

2.1.1.4 Fuel Specifications.

A preliminary fuel specification for the antimisting fuel will be developed to identify the acceptable tests and ranges of parametric values for these types of fuels, through the following efforts:

a. Use of base kerosene fuels derived from sources such as Alaska north slope crudes, synthetic crudes, shale crude, etc., will be addressed as to what impact will result on the antimisting fuel performance in all of the areas mentioned in these subphases. These considerations will address the critical specification sections or requirements that are affected to the most extent. Also of consideration is the nature of domestic fuels with respect to their geographical origin.

The focus of this whole subphase will be to identify those characteristics that comprise a system of detection of the antimisting and operational character of the candidate fuel.

2.1.1.5 Production.

The techniques, procedures, and equipment requirements to produce antimisting fuels, including the associated blending, blending rates, and storage considerations will be examined through the following group of individual but related efforts.

Projects to address the factors that affect the quality of the resultant antimisting fuel as a result of the blending process will be addressed. These include blending location (refinery, airport tankage system, aircraft inlet, etc.), technique, production rate potential, and variations resulting from the use of alternative base fuels.

The actual costs associated with the blending and production of the antimisting fuel will be assessed. Histories and projections based on the results of the previous subphase work will be monitored to anticipate cost problems or plateaus.

Analyses of storage character of the antimisting fuel will be made to assure that the antimisting qualities are not degraded by time. Since most aircraft retain a small portion of fuel from each on-loading, combinations of older antimisting fuel batches in varying quantities with freshly made fuel batches will be evaluated.

2.1.2 Large-Scale Evaluations.

Facilities capable of providing the ability to approximate full-scale crashes will be utilized to extend the laboratory-scale work closer to and in more agreement with the actual crash conditions.

This area of endeavor will require careful consideration of all facets of impact-survivable crash situations. The intent is to graduate in reverse from the actual crash to the laboratory scale. In the process, at least two major steps are envisioned.

One step up from the laboratory scale are large simulation facilities where velocities of air and fuel discharge rates can be duplicated. Such facilities give the most flexibility in examination of conditions. Their conditions should be the most easily repeatable outside of the laboratory. The next step is the actual crash of aircraft and/or aircraft components configured to represent some or all aspects of the laboratory and full-scale parameters. Possible vehicles in this type of testing are retired or surplus military aircraft which can be either tethered to crash under controlled conditions or released from a catapult facility.

All of these possible approaches will be considered in the conduct of the following tasks:

a. Because it is desirable that the antimisting fuel be equally functional in all classes and sizes of aircraft relative to their subsequent crash conditions, it is necessary to relate the results of variable size tests to one another. This area of crash relatability will also give assurance that laboratory testing of the fuel is an acceptable means of screening of candidates.

b. Regardless of the aircraft type or configuration, sufficient test and analysis must be accomplished over the expected range of crash parameters to assure the effectiveness of the fuel. Inherent in this analysis is the need to identify the type and use of instrumentation that will give the required valid data for consideration.

c. The culmination of all of the work in the preceding subphase efforts will be the identification of appropriate crash vehicles, their procurement, their preparation for test, and identification of the site upon which the test crashes will be conducted.

2.1.3 Cost/Benefit Consideration.

While the end result of the development will be strongly influenced by the cost/benefit aspects of the modified fuels usage, the analysis emphasis is placed on determination of the costs and cost projections for consideration of the antimisting fuel.

2.1.4 Feasibility Decision.

The criteria to be relied upon to determine feasibility of the use of the antimisting fuel in civil aviation will, of necessity, be governed by the success of the work of the first phase in resolving problem areas that may exist. The first criterion, therefore, is whether insurmountable technical problems exist. It is

expected these, if they exist, will surface during the Basic Tests/Characteristics and test work in the first part of 2.1.1. Because of the obvious differences between normal fuels and the antimisting fuel, it would appear probable that some aspect of engine, aircraft, and/or airport hardware or systems may require change. The degree of change required to achieve the overall goal of the antimisting fuel program is an important criterion. It is extremely desirable that these changes be minimal. Changes in filter mesh size, combustor nozzle orifice diameter, and fuel manifold pressure for primary or secondary flow initiation are examples of degrees of change that would be easiest to accommodate, although careful consideration of all possible change impact must assume importance.

Changes in the primary to secondary airflow split in the combustor, elimination of filters below a size that are needed to exclude ordinary grit or fuel contamination, or required increases in fuel pressure which would alter pump and control operation are much more significant and would represent a need for closer consideration of the feasibility decision.

The extreme would be represented where the aircraft fuel system would require significant revision (e.g., the effectivity of the engine fuel/oil heat exchanger is seriously impaired or the allowable storage time at airport facilities was altered). In such an instance, the criterion for feasiblity would most likely require the benefit potential to be extremely high for a favorable feasibility decision to be issued.

2.2 PHASE—II FULL-SCALE VALIDATION.

The demonstration portion of the development program for antimisting fuel will employ either FM-9 or that candidate fuel from Phase IIA which demonstrates the best overall performance.

The three major parts to this phase are the ground and flight test, the full-scale aircraft crash test, and the establishment of the final cost/benefit aspects of the fuel's usage.

2.2.1 Full-Scale Ground and Flight Testing.

The first major test effort in this final part of the overall development program is the conduct of ground and flight testing with the candidate fuel. As a precautionary measure, conventional fuel will also always be on board. The ground and flight test aircraft will have one engine and its aircraft support system dedicated to the antimisting fuel.

These test efforts are to demonstrate the validity of information gained from laboratory and ground test described in prior sections.

A basic flight envelope will be proled to assure that significant problem areas have not been overlooked. As a minimum, certain flight profiles such as maximum rate of descent, altitude relight, operation in turbulent weather, and exposure to weather (water, icing) extremes will be demonstrated. An estimated 50 hours of flight test time to reach basic conclusions is planned.

2.2.2 Full-Scale Crash Test.

The culmination of the development test work is the full-scale crash demonstration of an aircraft fueled with the antimisting fuel. It is proposed that the crash vehicle be impacted into a preselected course that would supply the appropriate ignition exposure to show acceptability of the fuels characteristics.

2.2.3 Final Cost/Benefit Analysis.

The final step in the development of the antimisting fuel is the detailed compilation, analysis, and judgment process of establishing the cost of the fuels introduction and use balanced against the potential benefit in the saving of lives, recovery of equipment, and possible reduced insurance costs.

The final result of this analysis may indicate that the previous approach of limited or selective use of the fuel is required to permit viable cost-benefit ratios or that the cost-benefit factors may only be realized in a certain percentage of accident occurrences. All such information will be assimilated to produce a recommendation as the introduction of the fuel into the civil aviation operations and in what time schedule such introduction is considered attainable.

2.3 PHASE IIA—CANDIDATE FUELS EVALUATION.

The continued development of FM-9 will be paralleled by an alternate candidate fuels evaluation if a positive decision of feasibility for an antimisting fuel program is made during Phase 1. This second phase will identify, investigate, screen, and develop the most promising alternate antimisting fuel candidate.

Antimisting fuel candidates, other than FM-9 or its derivatives, will be identified through solicitation of industry, the academia, and other government(s). Encouragement to embark on development of such antimisting fuels will be made through the application of funds as "seed money." These funds in the amount of approximately $500,000 will be made available to encourage and support industry development of alternate fuels. The requirement on the part of industry will be to submit data and other information that will substantiate that their proposed fuel is as good as, or better than the FM-9.

In such an instance, parallel development of this alternate fuel will be carried with the FM-9. By FY-1983, either failure of the FM-9 or advancement of the alternate fuel to a position much superior to FM-9, will govern which fuel is used in the Full-Scale Validations.

The elements of this development process are established in the following sections.

2.3.1 Basic Test/Characteristics.

These basics are identical to those defined in sections 2.1.1.1 through 2.1.1.5 insofar as the utilization of each test, etc., is concerned. With respect to the individual candidate antimisting fuel, each and every test etc., may not be

required. The composition or structure of the candidate may be such as to permit exclusion of the requirement of certain tests. For example, if the candidate does not employ the use of high molecular weight additives, those tests, etc., that relate to high molecular weight additive fuels may be omitted. Also, the investigations under Phase I may show that suspected problem areas do not, in fact, exist; these areas, therefore, need not be examined in the screening process.

This development will place the primary emphasis on the solution of airplane-oriented problems. In these areas, research will be continued to prepare for the use and demonstration of the fuel's capability of effectively and properly operating in a full-flight environment. Definition of the fuel specification will be finalized.

Continued work in the areas of production capability and the economics of its production will be further defined. In addition, the logistical aspects of supply of the fuel will be under examination.

2.3.2 Large-Scale Evaluations.

The large-scale evaluations to be conducted on the candidate antimisting fuels will consist of examination of the flammability characteristics in the Wing Fuel Spillage Facility at the FAA's Technical Center in New Jersey. This evaluation will compare the relationship of the additive concentration to the relative velocity between air and fuel discharge. This facility will have been calibrated through larger size tests, using cashiered military aircraft in crash tests, to provide conditions nearer those to be expected in actual crashes.

2.3.3 Compatibility Resolution.

This initial area of investigation in the development of the prototype candidates involves such work as the reconfiguring (if necessary) of engine and/or aircraft fuel systems to an experimental status capable of allowing simulated flight testing. The output of this work will be the definition of typical revisions, retrofits, etc., necessary and will become an input to the economic considerations of each of the candidates.

2.3.4 Specification/Quality Control Requirements.

Parallel to the work of the previous section, identification of the degree each candidate adheres to specification and definition of the control procedures and techniques required to achieve thia adherence will be underway. The outcome of these investigations will again provide input also to the economical considerations for each of the candidates.

2.3.5 Production/Supply Techniques.

Also in parallel to the two previous sections, definition of production capabilities, limitations, and supply will be examined for each candidate. The ability to support the remaining major tasks involving supply of the candidate in moderate quantities for the large-scale, ground demonstrations of the flammability characteristics, the testing of the candidates under simulated flight conditions, and the final full-scale crash of aircraft fueled with the candidate modified fuel, will level credence to the projections of ability to meet operational demands.

2.3.6 Utilization/Economics.

All of the previous tasks under this subsection will provide data as to the problems of utilization of the fuels. Consideration again will be given to the selective introduction of the fuel to specific segments of the operational fleet. Likewise, the economics of the use of the fuel will be more fully appreciated.

It is expected that the major portion of the justification for use of the fuel will be derived during these tasks, with interpolation and extrapolation of the information to other classes of vehicles being based on this data.

2.3.7 Full-Scale Validation Preparation.

A most important work effort in this area is the selection, acquisition, and preparation of acceptable full-scale ground, flight and crash test vehicles.

Selection must consider the overall spectrum of equipments and ranges of operational parameters represented by the existing and projected civil aviation fleet. The large scale results of section 2.1.2 are instrumental in these decisions.

2.3.8 Proposed Scheduling and Recommended Funding.

Vehicles selected for these tasks must be representative of commercial aircraft. The availability of such vehicles is low and because of such scarcity, the proposed scheduling and recommended funding for this portion of the program is predicated on the use of the agency B720 in the crash test and the agency B727 in the flight and ground tests. To achieve the quality of confidence in the candidate fuels, these tests are of extreme importance.

The vehicle could be used with both candidates in separate portions of the vehicle (different candidate fuels in each wing) with a controlled ground crash providing a direct and recordable comparison of performance of each candidate. This approach has been considered in addition to the obvious choice of one fuel over the other.

A second vehicle would be used for the flight simulation with both candidate fuels onboard (although conventional fuel would be available as a backup or alternative in case of problems).

The time to prepare, properly instrument, and operationally check out the vehicles is lengthy, on the order of 24 months. The proper instrumentation preparations alone, require at least 12 months.

Prior to the commitment to such flight and crash vehicles, a major decision conference shall be scheduled with AVS and the Technical Center/AED management.

2.4 REGULATORY RECOMMENDATION.

Based on the results of these phases, sufficient technical information should be in hand to allow the agency to determine the degree of improved safety to be realized by the use of such antimisting fuels.

Similarly, sufficient economic and practicality information should have been derived to enable a decision concerning the economical reasonableness of required use.

APPENDIX A

MEMORANDUM OF UNDERSTANDING

MEMORANDUM OF UNDERSTANDING

between

THE GOVERNMENT OF

THE UNITED KINGDOM OF GREAT BRITAIN
AND NORTHERN IRELAND

represented by

THE UNITED KINGDOM PROCUREMENT EXECUTIVE OF
THE MINISTRY OF DEFENCE

and

THE GOVERNMENT OF THE UNITED STATES OF AMERICA

represented by

THE UNITED STATES
DEPARTMENT OF TRANSPORTATION/FEDERAL AVIATION
ADMINISTRATION

concerning

CO-OPERATION IN THE TESTING AND DEVELOPMENT

of

ANTI-MISTING KEROSENE AND RELATED EQUIPEMENT

SHORT TITLE

AMK

SECTION I

INTRODUCTION

A. The Government of the United Kingdom of Great Britain and Northern Ireland, represented by the Procurement Executive of the Ministry of Defence (MOD (PE)) and the Government of the Unites States of America represented by the Department of Transportation, Federal Aviation Administration (DOT/FAA) with the purpose of saving lives and property through reducing the number and severity of fires following aircraft accidents in which there are survivors of the impact, intend to co-operate in the examination, development and testing of anti-misting kerosene fuels and of equipment related to the use of such fuels.

B. This co-operation will be undertaken by the MOD (PE) and the DOT/FAA each pursuing with their associates and contractors a part of the program of work set out in the Appendix to this Memorandum of Understanding.

C. This Memorandum of Understanding sets out the arrangements and procedures established by the Governments for co-operation in the carrying out of the program of work.

SECTION II

DEFINITIONS

In this Memorandum of Understanding:

(1) "Government" means the MOD (PE) or the DOT/FAA as the context may require; and "Governments" mean the MOD (PE) and DOT/FAA.

(2) "Program of Work" means the work set out in the Appendix to this Memorandum of Understanding.

(3) "Related Work" means work relating to anti-misting safety fuels for use in aircraft carried out before the day of entry into operation of this Memorandum of Understanding by the representatives or agencies or by an agent or contractor of either of the Governments or by a body under the control of either of the Governments.

(4) "Facility" means a laboratory test location or research establishment under the control of or under contract to one of the Governments.

SECTION III

MANAGEMENT

A. Each Government will appoint initially three members to a Management Group, whose function will be to undertake on behalf of the Governments the review of policy relative to, and general direction of, the program of work. Meetings of this Management Group will be held alternately in the United States and in

the United Kingdom, and will be convened by a chairman, chosen from the members appointed by the host country. In the case of the United States, the co-chairman, and one other, will be from the DOT/FAA and the third will be from the National Aeronautics and Space Administration. In the case of the United Kingdom, the co-chairman will be from the MOD (PE) and the one representative each from the Department of Industry and the Civil Aviation Authority.

B. The Management Group will meet, as required, to review progress and establish program guidance and priorities at significant decision points in the program. It is expected that this will normally be not more than twice and not less than once a year. It is hoped in particular that a decision can be taken by the Management Group as early as possible, within the first two years of operation of the Memorandum of Understanding, as to the overall viability of this program of work. Such a decision will take into account the technical issues, the potential cost, and the prospects for international implementation of anti-misting kerosene fuels.

C. The Management Group will approve the appointment of two Project Officers, one from the DOT/FAA and one from the MOD (PE). These Project Officers will act alternately as chairman of a joint Technical Group to be responsible for the technical supervision of the program. Each Project Officer will select, with the approval of the appropriate National Co-Chairman of the Management Group, a maximum of four members each from the United States and the United Kingdom respectively for the Technical Group. In addition, as necessary, the two Project Officers may invite additional representation from specialized areas of technical expertise and experience.

D. Each Project Officer, advised by the Technical Group, will be responsible to the Mangement Group for:

(a) The implementation of his own Government's respective part of the program of work.

(b) The co-ordination of, and any modification of, the parts of the program of work. Modifications to the program will be effective provided that they are set out in writing, signed by both Project Officers, and endorsed by the Management Group.

(c) Exchange of information arising from the program of work and related work in accordance with Section VI of this Memorandum of Understanding.

Meetings of the Technical Group will normally be held alternately in the United States and the United Kingdom, and will be arranged by the Project Officers as the work program requires.

The Project Officers will report, as required, to their respective Management Group Chairmen and may be invited to be in attendance at the meetings of the Management Group.

SECTION IV

COSTS AND SUPPLY OF MATERIALS

A. The cost of performing any item of the program of work will be borne by the Government in whose facility the item of work is performed unless otherwise specifically agreed by the Management Group.

B. The supply of information, material, or equipment by one Government to the other for the purpose of carrying out the program of work will normally be at the cost of the recipient Government but the cost chargeable to the recipient Government will be limited to the actual cost of procurement by the supplying government plus normal transportation, insurance costs, and identifiable taxes and customs duties. These arrangements may be varied in specific instances by the Management Group.

C. Either Government may loan to the other information, equipment or material.

D. The recipient Government will use the information, material or equipment only for the purpose of the program of work and in cases of loans, will return the information, material, or equipment at the request of the supplying Government and in accordance with the applicable law.

E. Any arrangement necessitating transfer of funds, arising out of the transfer or loan of information, material, or equipment from one country to the other will be the subject of a separate arrangement between the Government or their respective agencies.

SECTION V

ACCESS TO FACILITIES

A. Each Government will afford all the members of the Technical Group appointed by the other Government (and any person acting for the other Government and authorized by the two Project Officers) access to its facilities for the purpose of aiding appreciation of the performance of any item of the program of work which may be in progress at the facility.

B. This access will be subject to reasonable notification and to the normal security restrictions in existence at the facility and will be subject to the provisions of Section VI and VII of this Memorandum of Understanding.

SECTION VI

EXCHANGE, USE AND COMMERCIAL SECURITY OF INFORMATION

A. The Governments intend, subject to the rights of third parties, to exhange regularly information in their possession and which relates to their respective part of the program work. The information will be exchanged only through the medium of or with the concurrence of the Project Officers. All

information exchanged will be, so far as is practical, in the form of documents.

B. The exchange of information will be on the basis that the information is supplied only for study and evaluation by the recipient Government and that the information will not, without the prior approval in writing of the Government supplying the information, or the owner of the information, be passed to a third person except as may be required by applicable law or published or used for the design, development, or improvement of equipments, chemical products or processes.

C. In furtherance of paragraph B above, each Government will make every effort that it legally may to maintain the information free from any liability to disclosure under any present or future legislative provisions. Each Government may mark documents transmitted to the other with words indicating their owner, their country of origin, that they relate to the program or work, and that they are furnished under conditions of confidence (i.e., are not to be disclosed to or used by a third party without the prior permission of the transmitting Government) or alternatively establishing the conditions of release. The recipient Government will confirm that the documents are received under the conditions indicated.

D. At the specific request of the transmitting Project Officer setting forth the reasons for the request, the intended recipient Project Officer will review documents prior to formal receipt and advise the other Project Officer of his Government's view of its ability to maintain the confidentiality of the documents under applicable law. In doubtful cases, the Project Officers will, consult concerning what steps can be taken to provide for confidentiality. It is the understanding of the Governments that this provision should be invoked only in the most unusual circumstances.

E. Each Project Officer will ensure that any request under applicable law for disclosures of information in documents originating in the other country and furnished in accordance with this Memorandum of Understanding is promptly notified to the other Project Officer to afford the latter the opportunity to object to disclosure. The notification will identify applicable time limits and the legal principles involved in the request. If the Government processing the request determines that the requested information cannot legally be withheld, the Government's Project Officer will so advise the other Project Officer sufficiently in advance of the projected disclosure date to permit the latter to initiate whatever steps are deemed appropriate. In cases involving loaned information, the information will be returned to the lender, in accordance with the applicable law.

F. Each Government will grant to the other, or to a person nominated by the other, a licence on fair and reasonable terms to use, for commercial purposes in the United Kingdom and the United States and in other countries to which the licence may be extended under relevant laws and regulations, patented inventions and confidential technical information owned by the Government granting the licence and arising out of its respective part of the

program of work. Each Government will also grant a similar licence in respect of patented inventions and confidential technical information which it owns and which arose out of related work.

G. In the event that personnel of both Governments or their contractors participating in the program of work make a joint invention, design, or discovery, then both Governments will in accordance with their national laws take appropriate action to ensure that both Governments or persons nominated by either of them will have the right to the free use for commercial purposes, in the United Kingdom and the United States and in other countries to which the licence may be extended under relevant laws and regulations, of the joint invention, design, or discovery. The appropriate action may include making joint application for a patent and the assigning of the patent to one or jointly to both Governments and the granting of a free licence to one or both Governments or to a person nominated by either Government.

H. Any such licence as is referred to in paragraphs F or G of this Section will include the provision that the licencee will be obliged to inform the licencor of all developments, improvements, or inventions that the licencee may make in relation to the subject of the licence and will be obliged to grant a return licence on fair and reasonable terms to the licencor in respect of all the developments, improvements or inventions so made should the licencor so wish.

I. Each Government will use its good offices to arrange for a licence as described in paragraph F of this Section to be granted by a third person who may own relevant patented inventions, designs, discoveries or confidential information in respect of which Government does not have the right to grant such licences.

SECTION VII

MILITARY SECURITY

A. All classified information or material or equipment supplied in accordance with Section IV and VI will be protected in accordance with established security arrangements between the Government of the United Kingdom and the Government of the United States of America.

SECTION VIII

LIABILITY

Neither Government will be liable to the other for any damage, loss, or injury to personnel, material, or equipment occasioned by or during any activities undertaken pursuant to this Memorandum of Understanding.

SECTION IX

INTERPRETATION, APPLICATION AND MODIFICATION

Any disagreement regarding the interpretation or application of this Memorandum of Understanding will be resolved by consultation between the Governments and will not be referred to any international tribunal or third party for settlement.

The terms of this Memorandum of Understanding may be modified as provided in Section IIID or by the Governments. In the second case, any modification will enter into operation on signature by the duly authorized representatives of the Governments.

SECTION X

ENTRY INTO OPERATION AND TERMINATION

A. This Memorandum of Understanding will enter into operation on the date on which it is signed on behalf of the two Governments. The program of work will be pursued for at least two years from the date on which this Memorandum of Understanding enters into operation. Either Government may terminate the pursuit of its respective part of the program of work after giving 90 days notice in writing.

B. In the event that one or both Government terminate their participation in the program of work the understandings concerning exchange, use and commercial security of information as set out in Section VI and concerning Military Security as set out in Section VII will remain in effect.

SECTION XI

SIGNATURES OF AUTHORIZED REPRESENTATIVES

A. The foregoing represents the understandings reached between the Government of the United Kingdom of Great Britain and Northern Ireland represented by the Procurement Executive of the Ministry of Defence and the Government of the United States of America represented by the Department of Transportation, Federal Aviation Administration upon the matters referred to therein.

UNITED STATES
represented by
DOT/FEDERAL AVIDATION ADMINISTRATION

By: Norman H Plummer

Title: **Assistant Administrator for International Aviation Affairs (Acting)**

Date: **June 1, 1978**

UNITED KINGDOM
represented by
MINISTRY OF DEFENCE PROCUREMENT EXECUTIVE

By: [illegible]

Title: Director of Research Programmes C

Date: 14 June '78

Appendix see over

APPENDIX

PURPOSE OF JOINT US/UK PROGRAM

A. The purpose of the joint program is to reach an early decision whether anti-misting kerosene (AMK) is a potential candidate for certification or whether its ultimate use in commercial service is too improbable to justify further work. If is envisaged that this decision will be made by the Management Group before the end of FY-80.

B. The critical questions in evaluating the future potential of AMK for worldwide commercial service have been identified as:

1. Can the additive be made available in adequate quantities and at an acceptable cost with adequate control of quality for worldwide deployment?

2. What degree of protection would AMK provide in post-crash fuel fires?

   a. a few minutes after refuelling; i.e., typically in the take-off case;

   b. at the end of a typical flight cycle; i.e., typically in the approach/landing case.

3. What changes, if any, are necessary to enable a civil aircraft to use AMK? For example, are changes necessary to the fuel system tanks, pumps, filters, etc., and/or to the engine fuel management system?

4. Is it feasible in day-to-day commercial operation to blend the additive with kerosene at the fuelling point?

5. To what degree must AMK be degraded before it is suitable for operation in an engine system, and how can this controlled degradation be achieved?

FEDERAL AVIATION ADMINISTRATION

ANTI-MISTING KEROSENE (AMK) FUEL PROGRAM

1. OBJECTIVE: Determine compatibility of an aircraft fuel system using AMK fuel.

   APPROACH: A fuel system rig that is representative of a typical commercial aircraft will be selected to process AMK fuel through representative mission cycles. Test and evaluations of components will be made, followed by a complete integrated fuel system evaluation. The effect of the systems operation on the fuel anti-misting characteristics as required to assess any loss in fire resistance capability will be evaluated.

2. OBJECTIVE: Assess the fire resistance capability of AMK conducted under representative impact-survivable crash conditions.

   APPROACH: Aircraft with large fuel capacity will be subjected to simulated survivable crash conditions to confirm the evidence available from small-scale test results. It is envisioned that up to two tests will be accomplished in FY-78 and a potential of 3-6 tests in FY-79.

3. OBJECTIVE: By fire test simulation, expand range of knowledge of fire resistance capabilities of AMK.

   APPROACH: A fire test rig will be developed that will provide a wider range of post-crash conditions than now exists. Data will be collected for increased dump rates over a range of velocities to supplement existing data.

4. OBJECTIVE: Develop a suitable method for degrading and measuring AMK fuel properties for use in aircraft turbine engines.

   APPROACH: A review will be made of concepts for the degradation of AMK. One or two of the most promising concepts will be experimentally evaluated. As a companion effort, methods or equipment as required to measure fire resistance quality of the AMK will be developed.

UNITED KINGDOM PROGRAM

1. OBJECTIVE: To develop methods of producing AMK at an acceptable cost and to an acceptable level of quality on a large scale.

   APPROACH: Problems arising in the worldwide manufacture of AMK will be investigated. In particular solutions will be sought to the problems of quality control of the additive/carrier fluid dispersion and the stability of such dispersions.

2. OBJECTIVE: To demonstrate the feasibility of blending FM9 with kerosene at the aircraft fuelling point at or near realistic aircraft fuelling rates.

   APPROACH: Final optimization of additive/carrier fluid dispersion will be made with the object of ensuring rapid blending of the additive with fuel and the development of fire resistance of the blend within an acceptable time. A suitable blender will be constructed capable of handling flow rates at or near full scale.

3. OBJECTIVE: To demonstrate the fire resistance of AMK under a wide range of conditions.

   APPROACH: Rocket-sled fire tests will be carried out on FM9 dispersions in a range of kerosenes of different chemical composition including fuels of relayed specification having lower flash points. Tests on fuels made from aged dispersions and on fuels degraded in typical fuel systems will be included.

4. OBJECTIVE: To investigate the feasibility of degrading AMK to an acceptable level by means of a rotary mechanical device.

   APPROACH: The rotary mechanical degrader already developed at RAE will be optimized and scaled-up.

5. OBJECTIVE: To demonstrate the compatibility of AMK with typical fuel system components and to determine the degree to which the fuel is degraded by such components.

   APPROACH: The effectiveness of typical fuel system components with AMK will be determined. The degree to which AMK is degraded by such components will also be determined.

6. OBJECTIVE: To determine whether AMK will give rise to serious problems in the presence of water.

   APPROACH: The compatibility of water with fuels containing FM9 will be determined over a range of realistic operational conditions.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

1. OBJECTIVE: Examine present day jet aircraft engine components with a view toward defining the problems associated with operating on AMK.

   APPROACH: Conduct all-up engine tests to map undefined areas needing further investigation. Concurrently, perform single combustor tests to characterize the effect of AMK on engine starting, altitude relight, mission, performance, deposits, liner temperature, efficiency, etc.

2. OBJECTIVE: Perform basic rheology studies to characterize AMK.

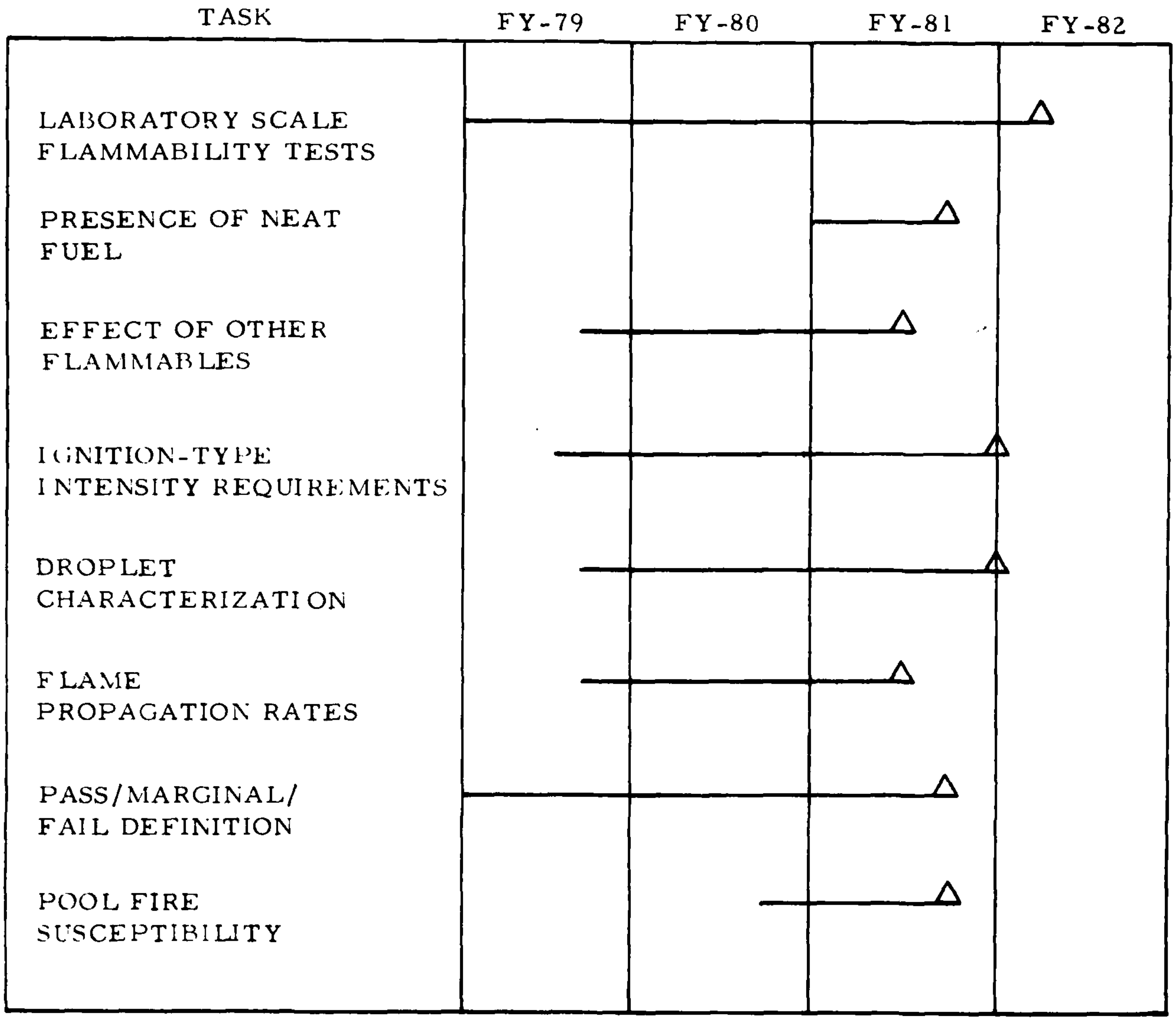
   APPROACH: Establish means of ascribing "quality" of degraded AMK. Examine degrader concepts. Investigate pool fire build-up inhibition.

APPENDIX B

PHASES I, II, AND IIA -PROPOSED SCHEDULING AND RECOMMENDED FUNDING

The following scheduling and funding charts and tabulations of this appendix B are arranged for clarity and understanding with related pages facing each other.

PHASE I - FEASIBILITY/FM-9 DEVELOPMENT
BASIC CHARACTERISTICS - FLAMMABILITY LIMITS
PROPOSED SCHEDULING



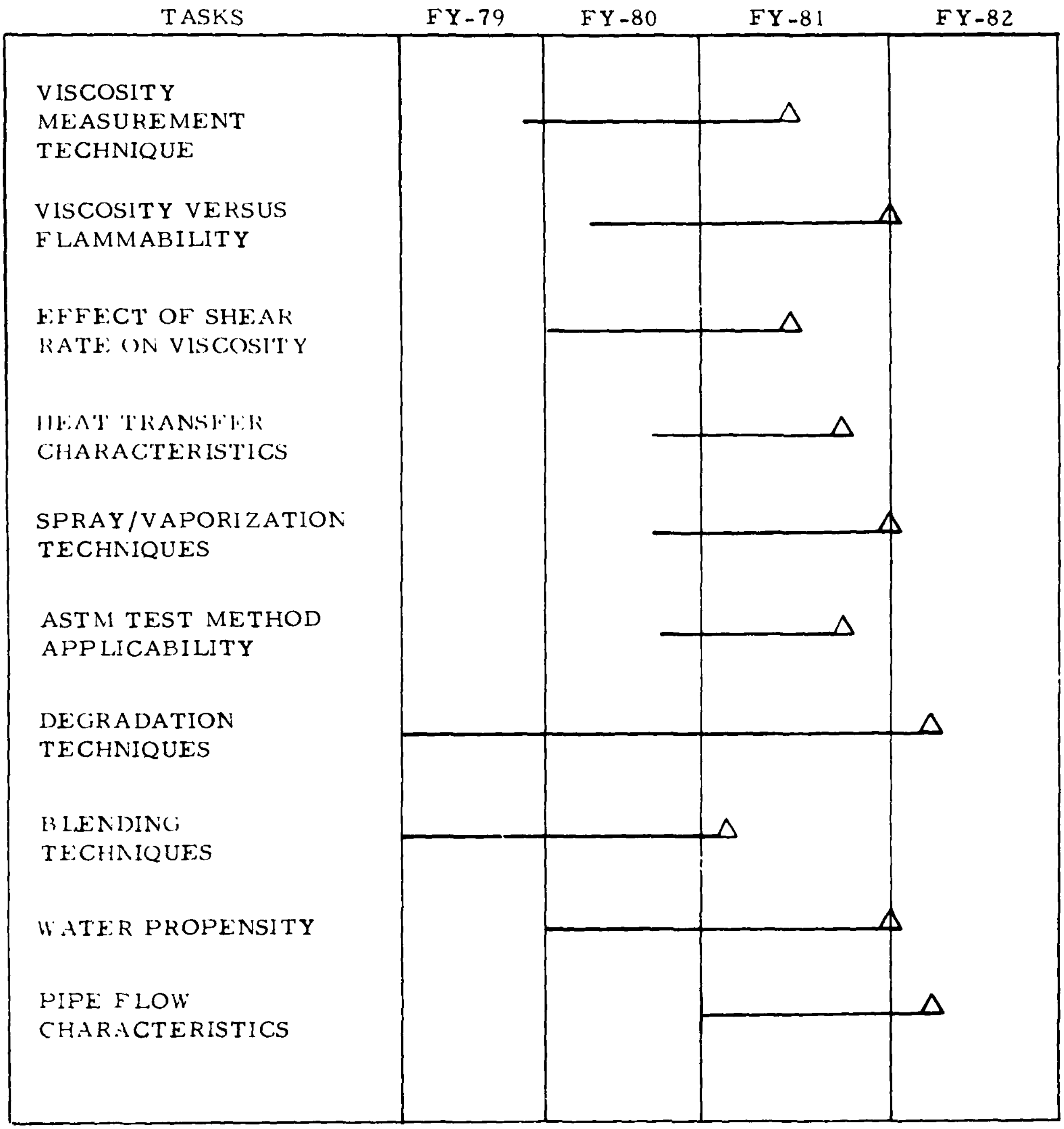
NOTE: △ = PLANNED COMPLETION

PHASE I - FEASIBILITY/FM-9 DEVELOPMENT
BASIC CHARACTERISTICS - FLAMMABILITY LIMITS
RECOMMENDED FUNDING REQUIREMENTS

TASK	FY-79	FY-80	FY-81
LABORATORY SCALE FLAMMABILITY TESTS	35K	22K	10K
IGNITION-TYPE INTENSITY REQUIREMENTS			35K
DROPLET CHARACTERIZATION		400K	50K
FLAME PROPAGATION RATES			75K
PASS/MARGINAL/ FAIL DEFINITION	11K		50K
POOL FIRE SUSCEPTIBILITY		30K	30K
TOTAL $	46K	452K	250K

NOTES: K = $1,000

PHASE I - FEASIBILITY/FM-9 DEVELOPMENT
BASIC CHARACTERISTICS - RHEOLOGY
PROPOSED SCHEDULING



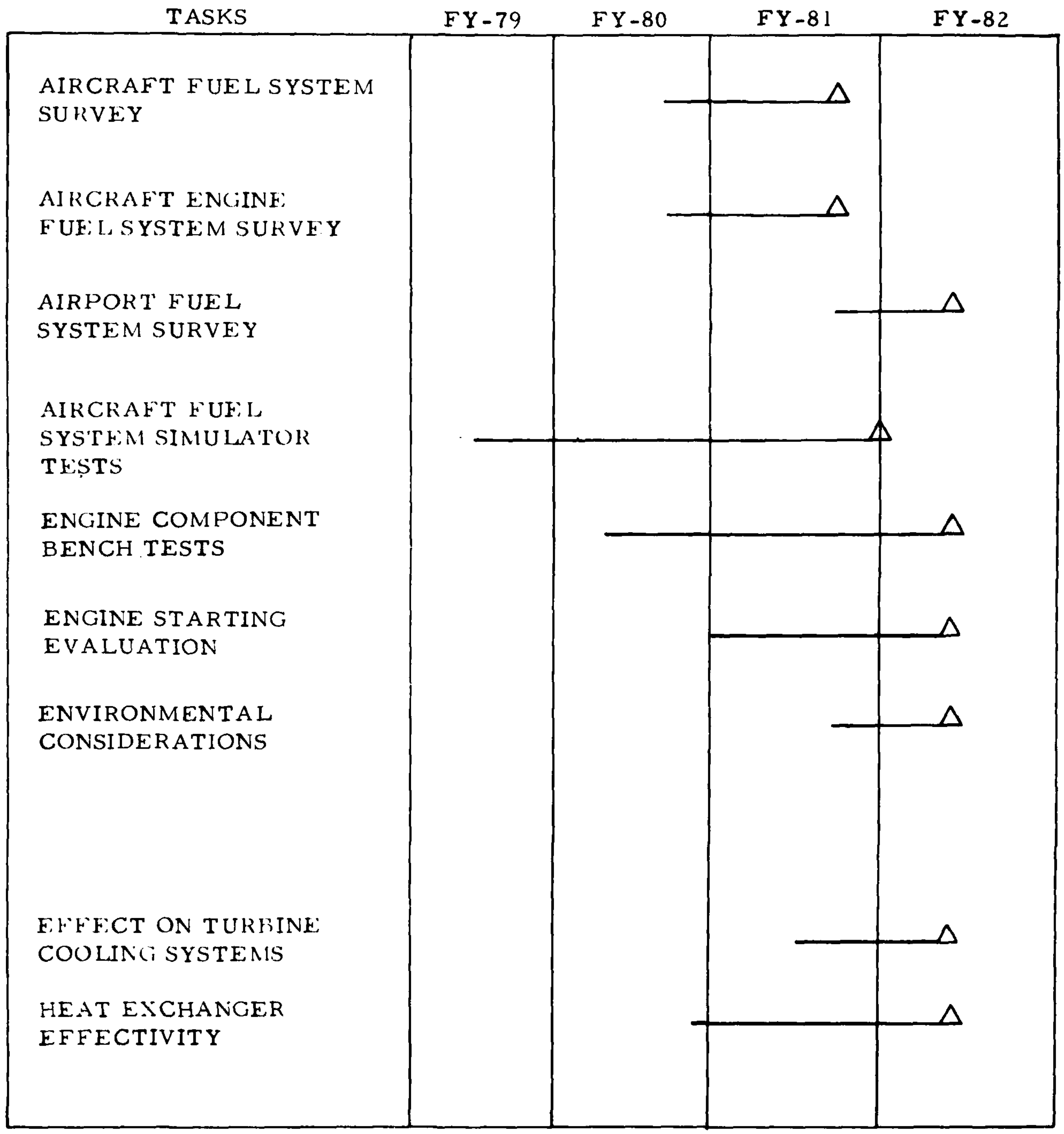
NOTES: △ = SCHEDULED COMPLETION

PHASE I - FEASIBILITY/FM-9 DEVELOPMENT
BASIC CHARACTERISTICS - RHEOLOGY
RECOMMENDED FUNDING REQUIREMENTS

TASKS	FY-79	FY-80	FY81
VISCOSITY MEASUREMENT TECHNIQUE	5K	10K	
VISCOSITY VERSUS FLAMMABILITY		10K	12K
EFFECT OF SHEAR RATE ON VISCOSITY		10K	
HEAT TRANSFER CHARACTERISTICS		95K	
SPRAY/VAPORIZATION TECHNIQUES		30K	
ASTM TEST METHOD APPLICABILITY		15K	13K
DEGRADATION TECHNIQUES	50K	250K	
BLENDING TECHNIQUES	150K	95K	
WATER PROPENSITY		95K	
PIPE FLOW CHARACTERISTICS			80K
TOTAL $	205K	610K	105K

NOTES: K = $1,000

PHASE I - FEASIBILITY/FM-9 DEVELOPMENT
BASIC CHARACTERISTICS - COMPATIBILITY
PROPOSED SCHEDULING



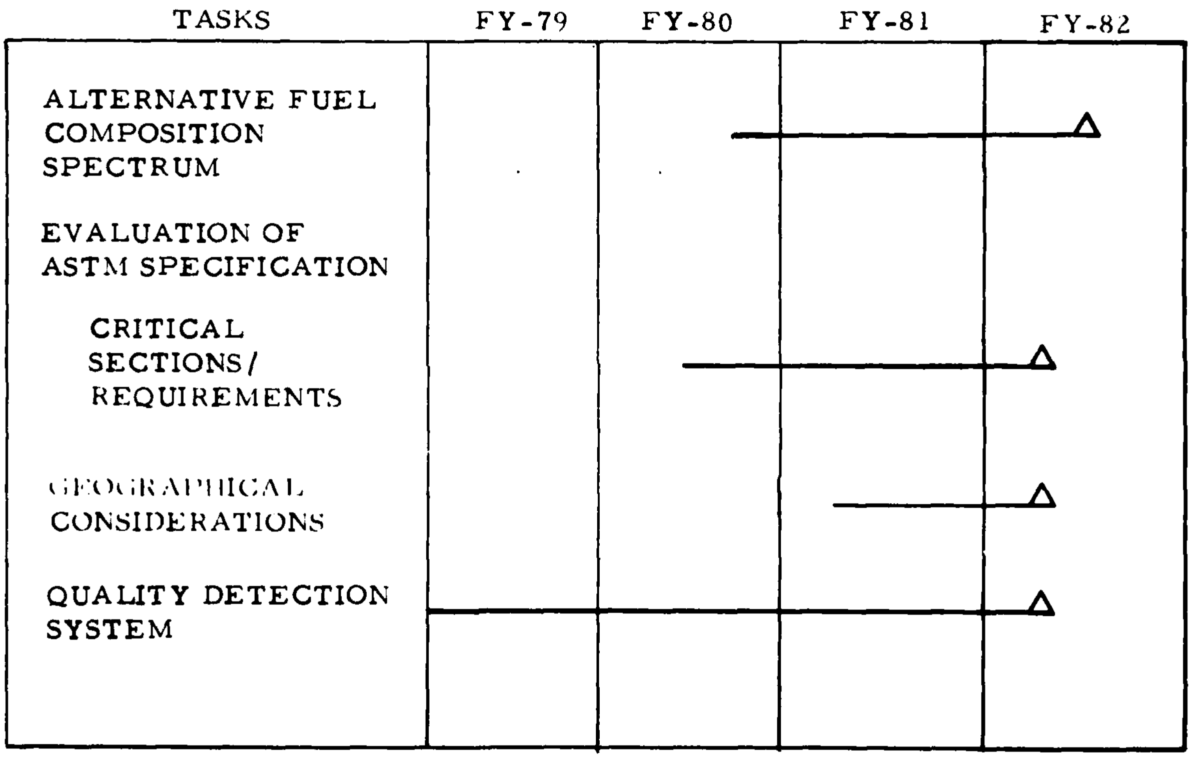
NOTES: △ = SCHEDULED COMPLETION

PHASE I - FEASIBILITY/FM-9 DEVELOPMENT
BASIC CHARACTERISTICS - COMPATIBILITY
RECOMMENDED FUNDING REQUIREMENTS

TASKS	FY-79	FY-80	FY-81
AIRCRAFT FUEL SYSTEM SURVEY		150K	
AIRCRAFT ENGINE FUEL SYSTEM SURVEY		150K	
AIRPORT FUEL SYSTEM SURVEY			50K
AIRCRAFT FUEL SYSTEM SIMULATOR TESTS	315K	200K	150K
ENGINE COMPONENT BENCH TESTS		80K	
ENGINE STARTING EVALUATION			150K
EFFECT ON TURBINE COOLING SYSTEMS			50K
HEAT EXCHANGER EFFECTIVITY			125K
TOTAL $	315K	580K	525K

NOTES: K = $1,000

PHASE I - FEASIBILITY/FM-9 DEVELOPMENT
BASIC CHARACTERISTICS - SPECIFICATION
PROPOSED SCHEDULING



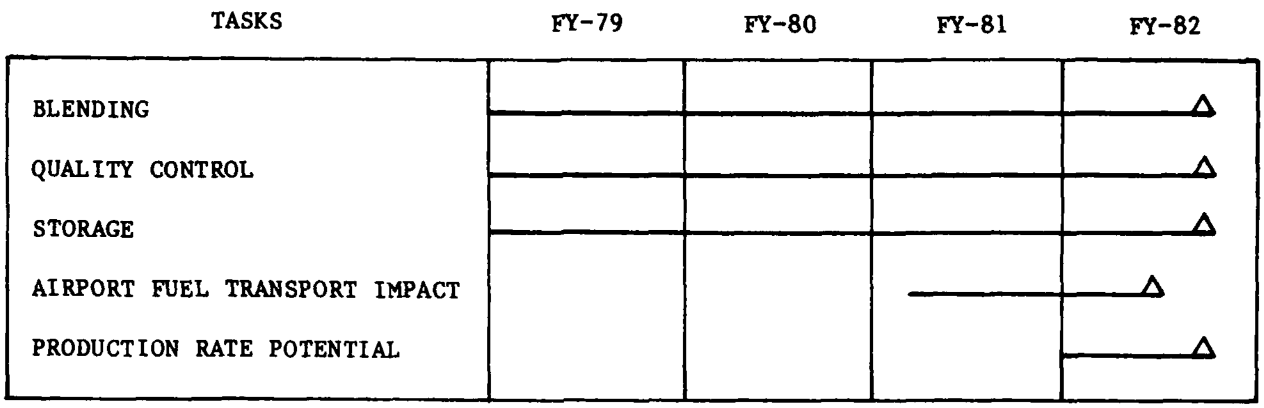
NOTES: △ = SCHEDULED COMPLETION

PHASE I - FEASIBILITY/FM-9 DEVELOPMENT
BASIC CHARACTERISTICS - SPECIFICATION
RECOMMENDED FUNDING REQUIREMENTS

TASKS	FY-79	FY-80	FY-81	FY-82
ALTERNATIVE FUEL COMPOSITION SPECTRUM				20K
EVALUATION OF ASTM SPECIFICATION CRITICAL SECTIONS/ REQUIREMENTS			50K.	10K
GEOGRAPHICAL CONSIDERATIONS			20K	
QUALITY DETECTION SYSTEM				80K
TOTAL $			70K	110K

NOTES: K = $1,000

PHASE I - FEASIBILITY/FM-9 DEVELOPMENT
BASIC CHARACTERISTICS - PRODUCTION
PROPOSED SCHEDULING



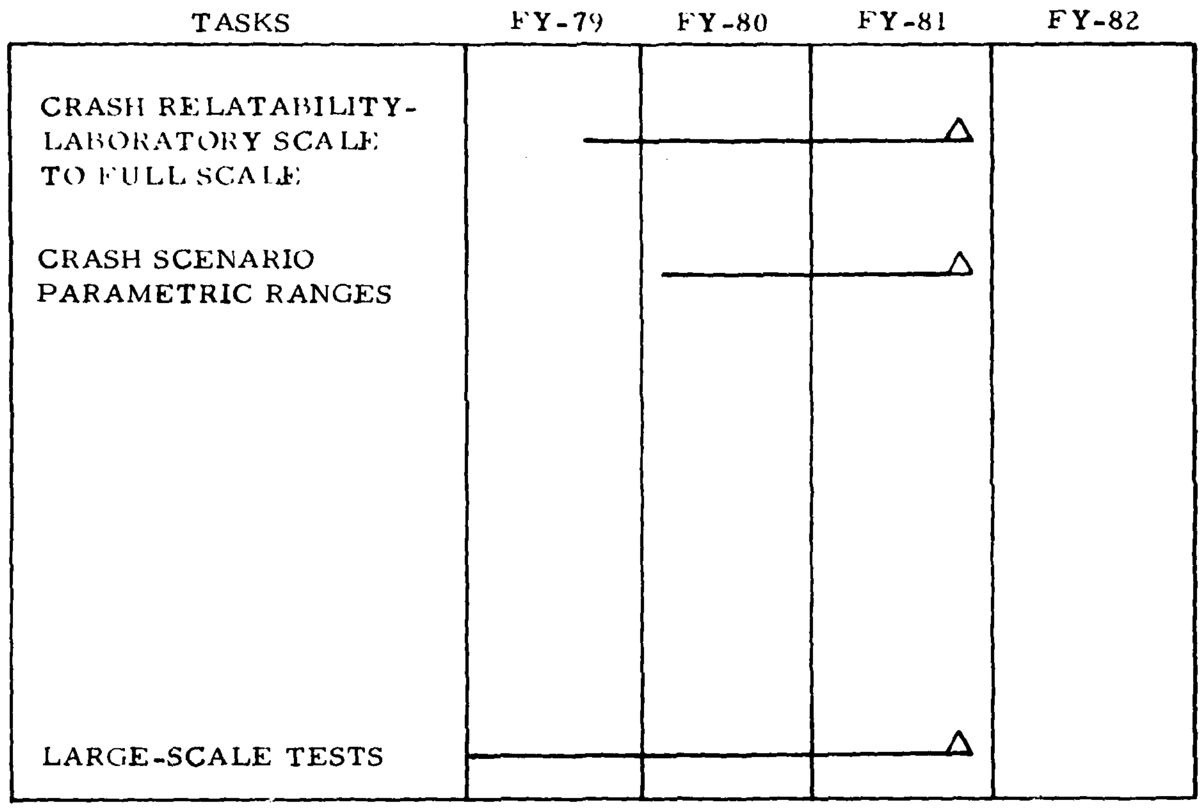
NOTE: △ = SCHEDULED COMPLETION

PHASE I - FEASIBILITY/FM-9 DEVELOPMENT
BASIC CHARACTERISTICS - PRODUCTION
RECOMMENDED FUNDING REQUIREMENTS

TASKS	FY-79	FY-80	FY-81	FY-82
BLENDING			20K	110K
QUALITY CONTROL			20K	60K
STORAGE			20K	75K
AIRPORT FUEL TRANSPORT IMPACT			10K	10K
PRODUCTION RATE POTENTIAL				20K
TOTAL			70K	275K

NOTE: K = $1,000

PHASE I - FEASIBILITY/FM-9 DEVELOPMENT
LARGE SCALE EVALUATIONS
PROPOSED SCHEDULING



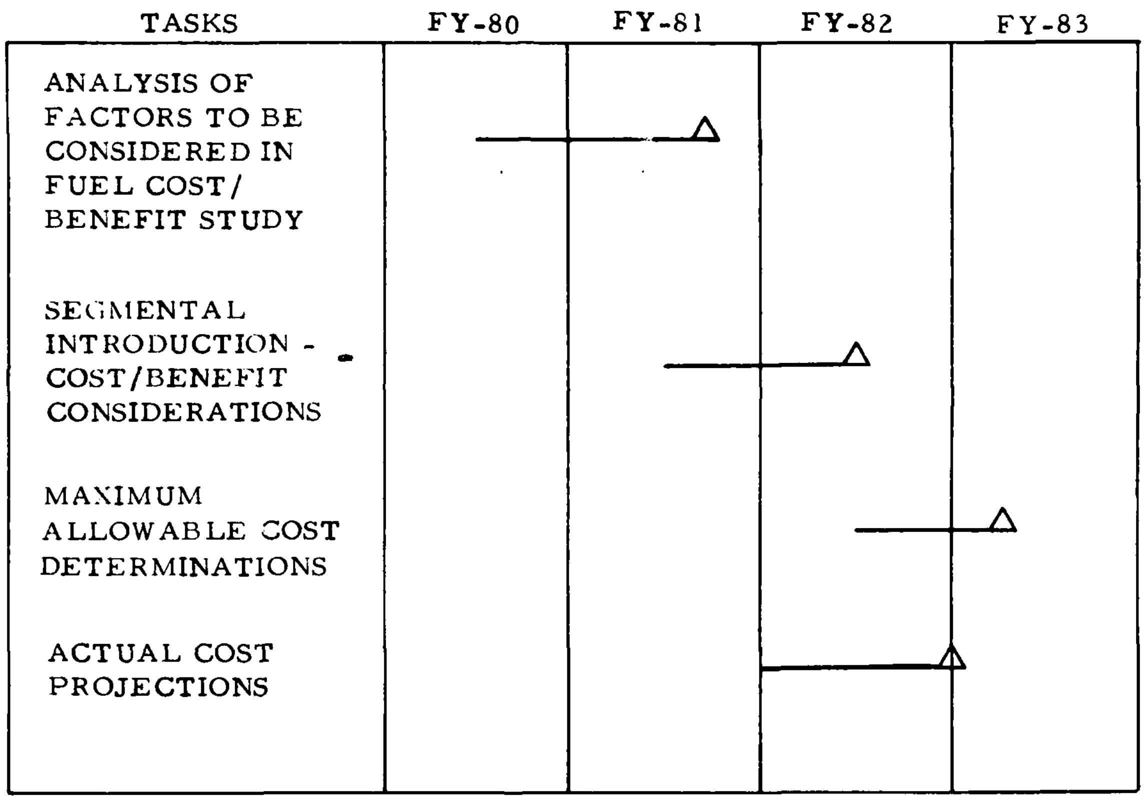
NOTES: △ = SCHEDULED COMPLETION

PHASE I - FEASIBILITY/FM-9 DEVELOPMENT
LARGE SCALE EVALUATIONS
RECOMMENDED FUNDING REQUIREMENTS

TASKS	FY-79	FY-80
CRASH RELATABILITY-LABORATORY SCALE TO FULL SCALE		100K
CRASH SCENARIO PARAMETRIC RANGES		30K
LARGE-SCALE TESTS	509K	40K
TOTAL $	509K	170K

NOTES: K = $1,000

PHASE I - FEASIBILITY/FM-9 DEVELOPMENT
COST/BENEFIT ANALYSIS
PROPOSED SCHEDULING



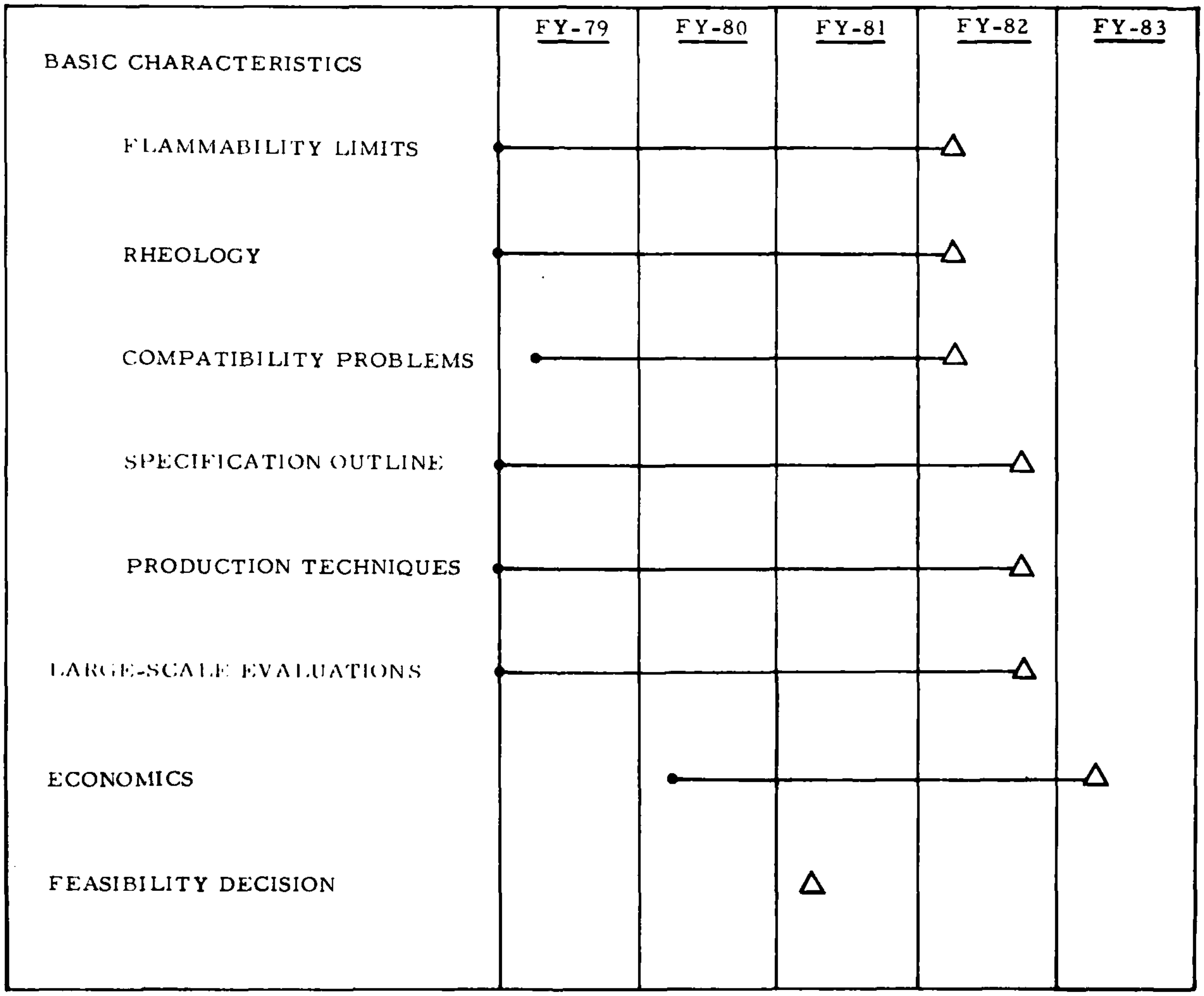
NOTES: Δ = SCHEDULED COMPLETION

PHASE I - FEASIBILITY/FM-9 DEVELOPMENT
COST/BENEFIT ANALYSIS
RECOMMENDED FUNDING REQUIREMENTS

TASKS	FY-80	FY-81	FY-82
ANALYSIS OF FACTORS TO BE CONSIDERED IN FUEL COST/ BENEFIT STUDY	100K	100K	
SEGMENTAL INTRODUCTION - COST/BENEFIT CONSIDERATIONS		50K	70K
MAXIMUM ALLOWABLE COST DETERMINATIONS			50K
ACTUAL COST PROJECTIONS			100K
TOTAL $	100K	150K	220K

NOTES: K = $1,000

PHASE I - FEASIBILITY/FM-9 DEVELOPMENT
ANTIMISTING FUEL PROGRAM
PROPOSED SCHEDULING SUMMARY



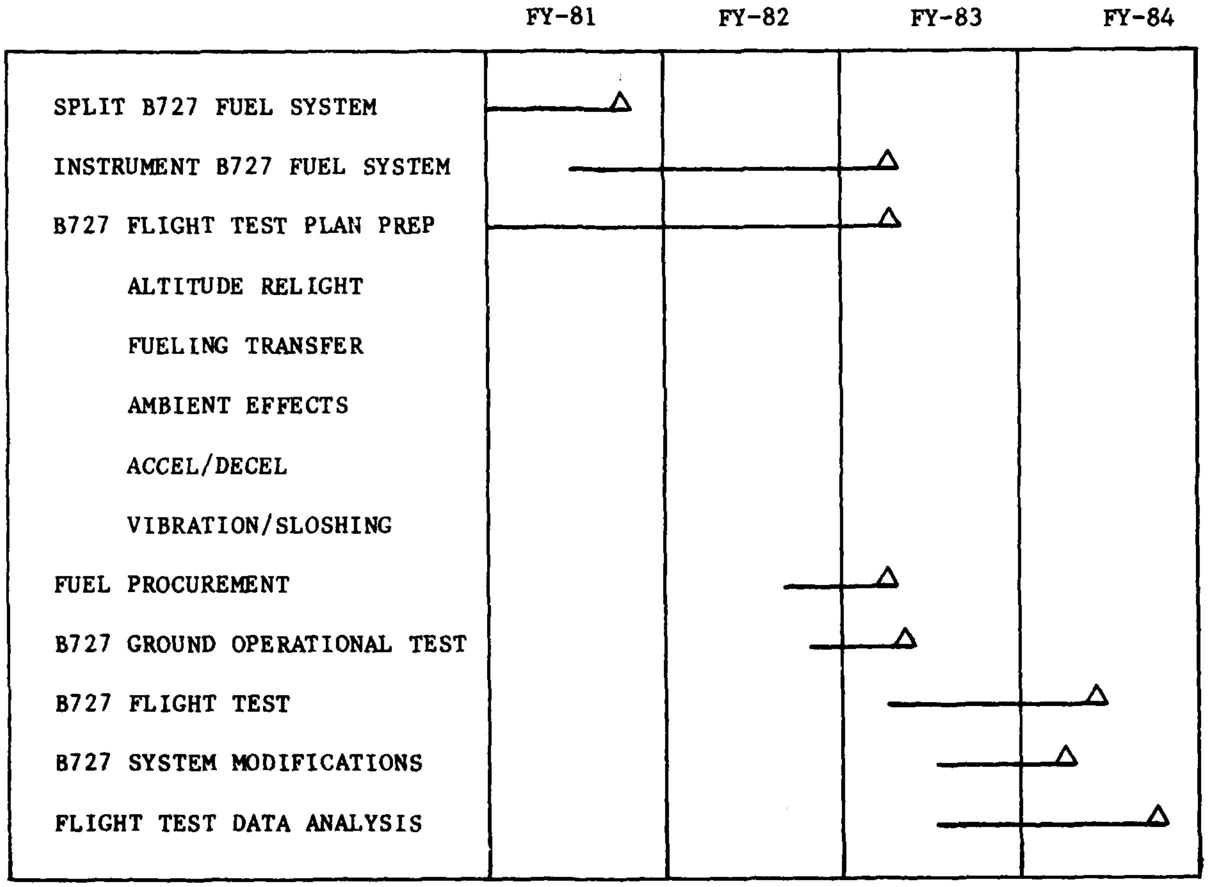
ANTIMISTING FUEL PROGRAM
PHASE I - FEASIBILITY/FM-9 DEVELOPMENT
FUNDING SUMMARY

Date for Feasibility Decision

	FY-79	FY-80	FY-81	FY-82	FY-83
BASIC CHARACTERISTICS					
Flammability	46K	452K	250K		
Rheology	205K	610K	105K		
Compatibility	315K	580K	525K		
Fuel Specification			70K	110K	
Production			70K	275K	
LARGE-SCALE EVALUATIONS	509K	170K	25K		
ECONOMICS		100K	150K	220K	
Subtotal $	1075K	1912K	1195K	605K	

Note: K = $1,000

PHASE II - FULL-SCALE VALIDATION
B727 FLIGHT TEST W/FM9
PROPOSED SCHEDULING

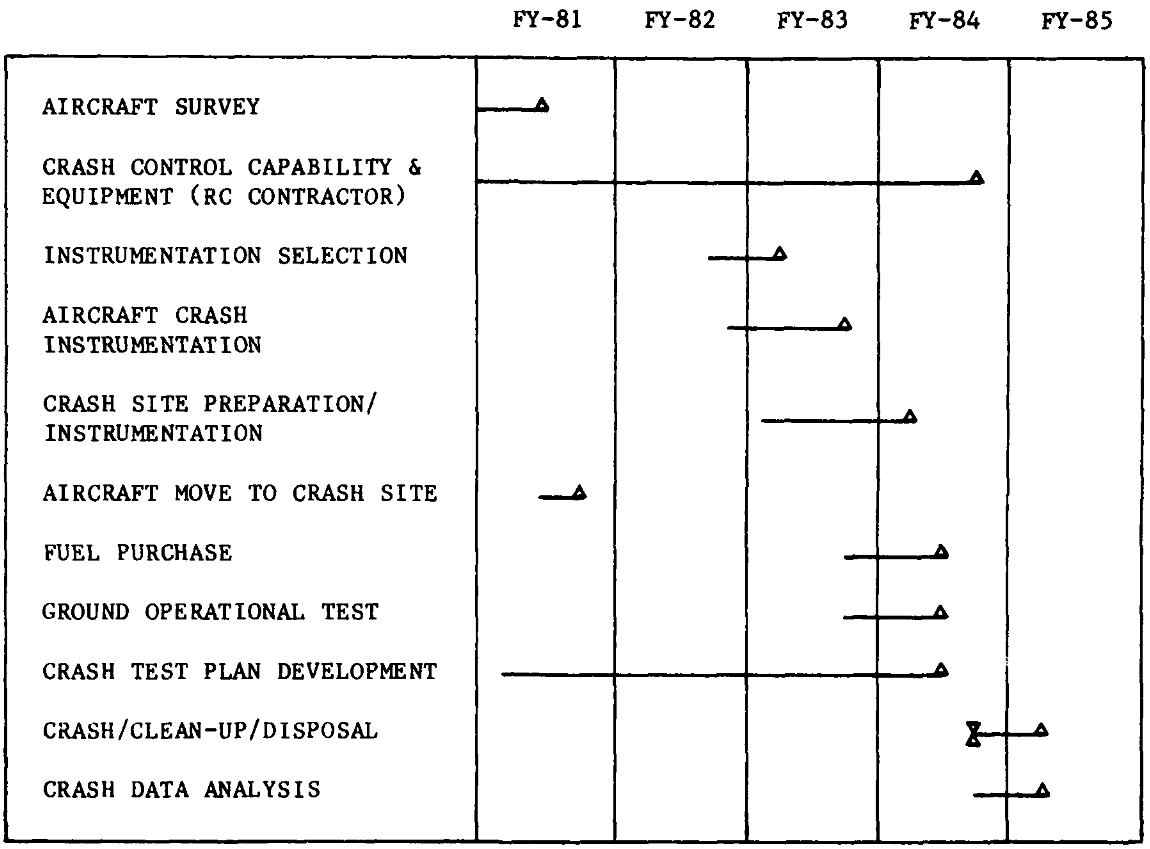


PHASE II - FULL-SCALE VALIDATION
B727 FLIGHT TEST W/FM9
RECOMMENDED FUNDING REQUIREMENTS

	FY-81	FY-82	FY-83	FY-84
SPLIT B727 FUEL SYSTEM	150K			350K
INSTRUMENT B727 FUEL SYSTEM	100K	150K	100K	
FUEL PROCUREMENT		200K	100K	
B727 GROUND OPERATIONAL TEST		220K		
B727 FLIGHT TEST			300K	200K
B727 SYSTEM MODIFICATIONS			100K	75K
FLIGHT TEST DATA ANALYSIS			75K	100K
TOTAL	250K	570K	675K	725K

NOTE: K = $1,000

PHASE II - FULL-SCALE VALIDATION
FULL-SCALE CRASH TEST
PROPOSED SCHEDULING

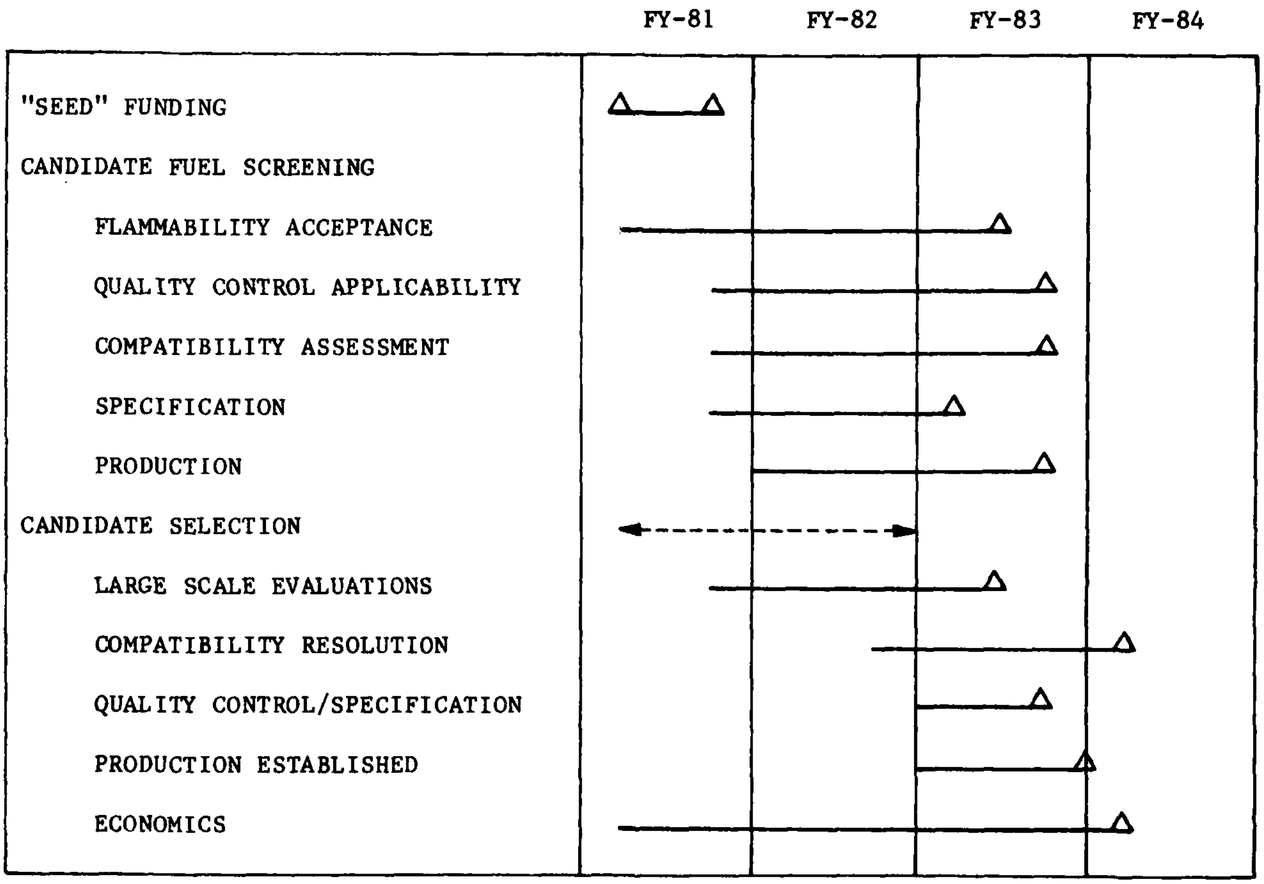


PHASE II - FULL-SCALE VALIDATION
FULL-SCALE CRASH TEST
RECOMMENDED FUNDING REQUIREMENTS

	FY-81	FY-82	FY-83	FY-84	FY-85
CRASH CONTROL CAPABILITY (RC CONTRACTOR)		300K	450K	150K	
AIRCRAFT CRASH INSTRUMENTATION		100K	450K		
CRASH SITE PREPARATION/ INSTRUMENTATION			500K		
AIRCRAFT MOVE TO CRASH SITE		225K			
FUEL PURCHASE			150K	150K	
GROUND OPERATIONAL TEST			150K	175K	
CLEAN-UP/DISPOSAL					350K
CRASH DATA ANALYSIS				60K	60K
TOTAL $		625K	1700K	535K	410K

NOTE: K = $1,000

PHASE IIA - CANDIDATE FUELS EVALUATION PROPOSED SCHEDULING



PHASE IIA - CANDIDATE FUELS EVALUATION RECOMMENDED FUNDING REQUIREMENTS

	FY-81	FY-82	FY-83	FY-84
"SEED" FUNDING	500K			
CANDIDATE FUEL SCREENING				
FLAMMABILITY ACCEPTANCE		100K	75K	
QUALITY CONTROL APPLICABILITY		200K	110K	
COMPATIBILITY ASSESSMENT		250K	250K	
SPECIFICATION		425K	150K	
PRODUCTION		90K	90K	
CANDIDATE SELECTION				
LARGE SCALE EVALUATIONS		275K	50K	
COMPATIBILITY RESOLUTION			125K	50K
QUALITY CONTROL/SPECIFICATION			40K	
PRODUCTION ESTABLISHED			60K	
ECONOMICS	50K	150K	150K	50K
TOTAL	550K	1490K	1100K	100K

NOTE: K = $1,000

APPENDIX C

MEMORANDUM OF UNDERSTANDING RELATIVE TO COOPERATIVE AIRCRAFT FIRE SAFETY RESEARCH

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
AND
FEDERAL AVIATION ADMINISTRATION
DEPARTMENT OF TRANSPORTATION

Memorandum of Understanding Relative to Cooperative Aircraft Fire Safety Research

I. PURPOSE The purpose of this Memorandum of Understanding (MOU) is to establish a basis of understanding for the conduct of fire research and the advancement of aircraft fire safety technology of mutual interest to the National Aeronautics and Space Administration (NASA) and the Federal Aviation Administration (FAA). NASA's program objectives relative to this MOU are to develop a technology base which will support improvements in aviation fire safety. The NASA objectives will be pursued through materials research, fuel chemistry, and aircraft systems analysis. FAA and NASA will conduct testing as necessary to validate results of their respective research projects. FAA's R&D program objectives relative to this agreement are to use basic technology developed by NASA and others to develop or recommend test equipment and methods, procedures, and standards for materials and fuel systems by which FAA and industry can upgrade aircraft fire safety.

II. OBJECTIVE Within the context of the above, the general area of aircraft fire safety research has been subdivided into the following three subprograms:

1. In-flight Propulsion Fire Safety

The NASA will:

(a) develop the technology for advanced fire extinguishing agents and their dispersal suitable for use in the severe engine compartment conditions associated with future turbine engines

(b) investigate and develop analytical methods for three dimensional analysis of turbine blade/rotor containment and/or deflection.

The FAA will:

(a) test and evaluate advanced extinguishers together with their associated dispersing systems for use in commercial aircraft

(b) utilize the analytical rotor burst technology to provide implementation criteria to protect critical airframe areas from excessive damage.

2. Fuselage Fire Safety

The NASA will:

(a) modify or synthesize low-cost and new polymeric cabin interior compounds, materials and construction which possess superior flammability, smoke, and toxic gas emission characteristics under full-scale cabin fire conditions and which can be developed to replace existing production materials

(b) develop composite material systems concepts for optimizing acoustic/vibration damping and minimizing intrusion of post crash external fires into fuselage and cabin

(c) conduct toxicity studies of pyrolysis and combustion products of advanced fire resistant polymeric materials

(d) develop incipient fire detection technology suitable for monitoring all unoccupied compartments in air carrier type aircraft, while parked or in flight

(e) conduct laboratory, sub-scale and full-scale burn tests to validate the advanced materials base technologies as applied to occupied and unattended portions of aircraft

(f) develop fire-resistant materials and secondary structures technology for coatings, windows, seats, partitions, etc.

(g) develop technology for improved cabin fire extinguishants compatible with physiological requirements for passengers and crew exposed to fire conditions

The FAA will:

(a) investigate and fire-test full-size or scaled air transport cabins equipped with candidate cabin/cargo compartment fire suppression/detection system. Cabin will be equipped with state-of-art or advanced interior materials or furnishings and tests will simulate both inflight and post crash fire conditions

(b) investigate and fire-test the ability of cabin class partitions, curtains, cabin headers, and cabin smoke control systems to minimize the propagation of smoke, gas, and heat between compartments

(c) investigate and test existing and proposed polymeric cabin interior materials and furnishings to develop methods and equipment for ranking materials for separate and/or combined combustion hazards such as flammability, smoke, and toxic gas, to support FAA regulatory processes. This task also

includes the identification and development of standard test instrumentation, procedures, and criteria compatible with the requirements for rulemaking. Test methods will be used which are compatible with full-scale realities.

(d) conduct toxicological and physiological tests to support the tasks described in item C and the aeromedical responsibilities of FAA

(e) develop cabin-fire computer modeling technique which will predict the time-history magnitude of combustion hazards from laboratory test data on materials

(f) develop scale cabin-fire modeling methods which will predict the time-history, combustion hazards of a cabin material, or materials system under full-scale fire conditions for a given ignition/combustion scenario equivalent to full-scale cabin fire

(g) conduct burn tests of transport cabin interiors to substantiate data needed to support the rulemaking process

(h) develop acceptable means of compliance with proposed regulatory requirements

The FAA and NASA will:

(a) develop compatible test programs to permit correlation of individual test data

3. Modified Fuel for Reduction of Crash Fuel Fire Severity

The NASA will:

(a) conduct basic chemistry studies to define the behavior of modified (safety) fuel under survivable crash conditions. This work will supplement the analytical studies underway in the FAA program

(b) investigate aircraft fuel systems components and turbine engine combustor performance with modified fuel and develop techniques for manipulating modified fuel in the system to preserve combustion and system efficiencies while at the same time retaining anti-misting benefits

The FAA will:

(a) conduct small-scale and large-scale tests to demonstrate the safety benefits of modified fuel in reduction of the post-crash fuel mist fire hazard

(b) establish the modified fuel additive and concentrations for evaluation of compatibility with turbine engines and fuel systems

(c) evaluate compatibility of modified fuel with aircraft fuel systems

(d) develop a modified fuel specification for qualification of modified fuel in turbine powered aircraft

III. PROVISIONS This MOU is of a general nature and intended to promote the development of the technology base and design criteria for reducing aircraft fire hazards and, if required, will be supplemented by individual interagency agreements with specific work statements and schedules mutually agreeable to each agency's respective program managers.

The agreement will be reviewed at least annually. Should either agency desire to terminate the agreement, a 90-day notice of intention to terminate will be sufficient to cancel the agreement. A 30-day notice of intention to modify the agreement will be given by either agency.

No interagency transfer of funds is necessarily implied in the execution of this MOU. Should specific tasks requiring such transfer be in the best interests of both agencies, it will be handled on an individual case basis, through an appropriate interagency agreement.

Contracts entered into by either agency under this program will be negotiated and administered in accordance with the cognizant agency's procurement practices. The other agency will be notified upon finalization of a contract for information purposes only.

Release of information to the public concerning results of tasks performed within the scope of this MOU shall be the responsibility of the sponsoring agency. In the case of jointly funded or otherwise supported programs, the specific interagency agreement will govern the information reporting procedure.

For and on behalf of the
Federal Aviation Administration
Department of Transportation

Associate Administrator for
Engineering and Development

For and on behalf of the
National Aeronautics and
Space Administration

NOV 10 1977

Associate Administrator for
Aeronautics and Space Technology